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Bart Verbeek

Dear PhotonicsNL Magazine reader,

The PhotonicsNL association continues to play a pivot role in the photonics development in the Netherlands. Two major articles in this issue of the Photonics Magazine will update you with the exciting activities in Twente and Eindhoven. During the Integrated Photonics Conference held in April, the Photon Delta initiative in Eindhoven as a photonic business accelerator was announced as well as the start of the Integrated Photonics Institute for scientific research in this exciting field where the Netherlands has a pole position with respect to the US and China. Fortunately, the University of Twente with the Applied Nanophotonics (ANP) cluster and Delft University of Technology with the Dutch Optical Centre are partner of this initiative to strengthen the Dutch photonics position in a coordinated way. The association PhotonicsNL is very happy with this development and will support it.

On the industrial side, a new venture was announced recently by the Panthera Group and YMK Photonics Co Ltd forming LioniX International BV acquiring our members LioniX, Satrax, XiO Photonics and OctroliX to provide a vertically integrated company in the field of Photonic Integrated Circuits (PICs). These PICs are based on its proprietary waveguide technology (TriPleX™), in addition to its other core competences microfluidics, optofluidics and MEMS.

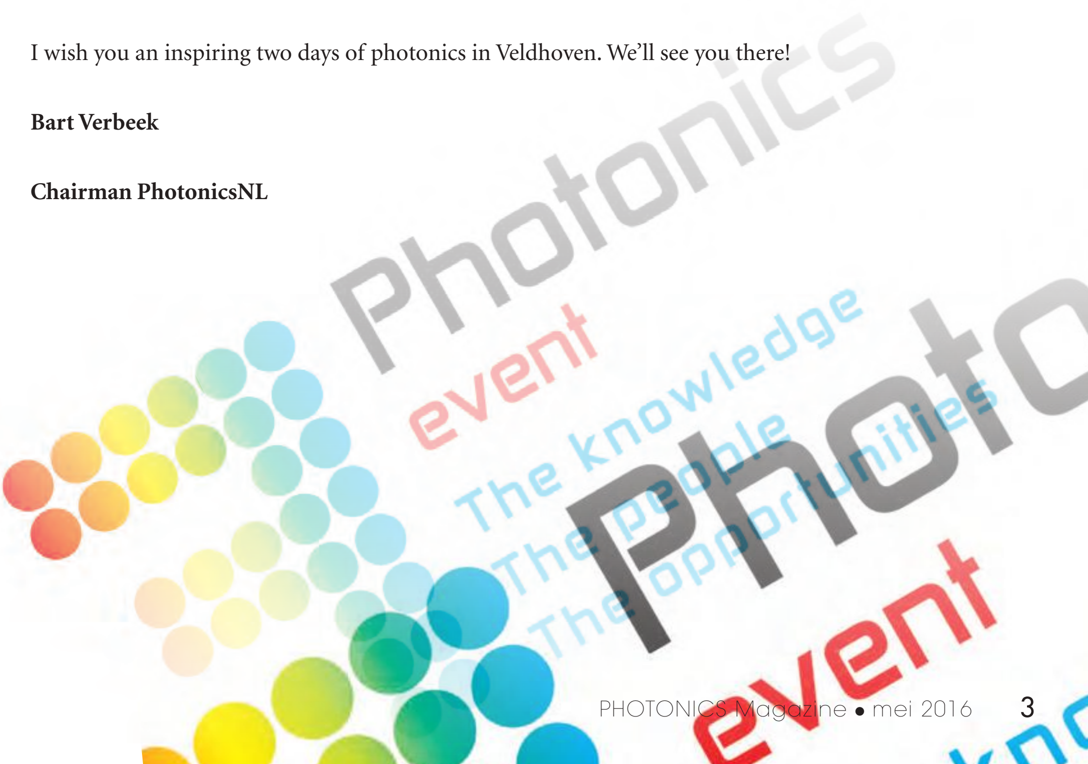
In this magazine you will also find a press release about Avantes who has been announced by the *Nationaal Business Succes Award Instituut* as winner of the Dutch Optical Instrument branch. On behalf of PhotonicsNL I take this opportunity to congratulate Avantes with this award.

The Photonics Event will take place in Veldhoven on June 1st and 2nd again together with Vision, Robotics &Mechatronics. On the first day, PhotonicsNL organizes two international workshops on Introduction to Photonics and Integrated Photonics for Sensors. The second day we will have our annual scientific Conference with exciting presentations and posters delivering the latest developments in Photonics. We are proud that Bert Jan Offrein from IBM Zurich will give the plenary invited talk to the conference. In connection to the Photonics Event, the European Photonics Venture Forum will be held attracting even more international participants. The full program can be found in the central folder of this issue of the Magazine.

I wish you an inspiring two days of photonics in Veldhoven. We'll see you there!

Bart Verbeek

Chairman PhotonicsNL



Dear PhotonicsNL-member, dear visitor of FE2016, dear reader,

Guus Taminiau

This edition of our Photonics Magazine is completely focused on our annual national Photonics Event 2016. Bart Verbeek, our chairman already gave the mainlines of the event. This edition is printed in two thousand copies, which is our largest edition ever and will be handed out to all the visitors of the event.

In the middle of this magazine you will find a separate section in which you can find all the information about the program, the exhibition, our Photonics Conference and the Meet & Match event on June 2nd.

On June 1st we offer you a special program starting in the morning with an introductory conference in which we will give a general overview about the importance of Photonics as key enabling technology for Europe. See the detailed description on page 2 of the middle section.

In the afternoon we have organized the workshop Integrated Photonics for Sensors together with our partner JePPIX (see page 3). JePPIX is the international platform for Photonic IC's (PIC's) and is hosted by Eindhoven University of Technology. On April 25th during the conference Photonics Integration the unique organization PhotonDelta went public. On page 7 you can read the interview by Jonathan Marks with Ewit Roos, Managing Director of PhotonDelta.

As a result of this announcement Photonics reached the front page of the Financieel Dagblad - a well-read Dutch business paper - with an article of Erik Hoving, Chief Technology Officer of our largest phone company KPN, titled: ***Without Photonics the Internet will crash!***

Probably all of you with a physics or photonics background will agree with this statement and won't be very much surprised. But most important result of the article is that, as far as I know, for the first time in Dutch history we have reached a broad public, and not at the least, attracted the attention of investors!

TELECOM

KPN stelt: zonder fotonica loopt het internet vast

Financieel Dagblad, April 29th 2016

And talking about Integrated Photonics on Nanoscale!
On Page13 you will find an impressive overview article of Sonia Garcia-Blanco of Twente University in Enschede. In this article she describes not only the disruptive R&D at the university (Mesa+ institute) but also the strong collaboration with several innovative photonic companies in the Twente region, covering the entire value chain from research to new innovative products.

I would like to finish by introducing Bert Jan Offrein, our Keynote Speaker. Bert Jan is Principal Research Staff Member at IBM Research in Zürich and will open our conference program on June 2nd at 9:55h.

Optical interconnects for computing systems and the need for integration

Optical interconnects play an increasingly important role in the intra-system communication in computing systems. To continue to scale system performance, new electro-optical integration approaches are required that increase bandwidth while reducing cost. An overview of chip-level and system-level integration concepts will be presented.

Reading the title and the short abstract of his talk I think you will agree that the subject perfectly matches with one of the main topics of our conference, Integrated Photonics, and in this case the perfect marriage with Micro-electronics!
On behalf of our PhotonicsNL board I wish you all a pleasant and successful staying at our 10th **edition** Photonics Event 2016!

Guus Taminiau, Director PhotonicsNL

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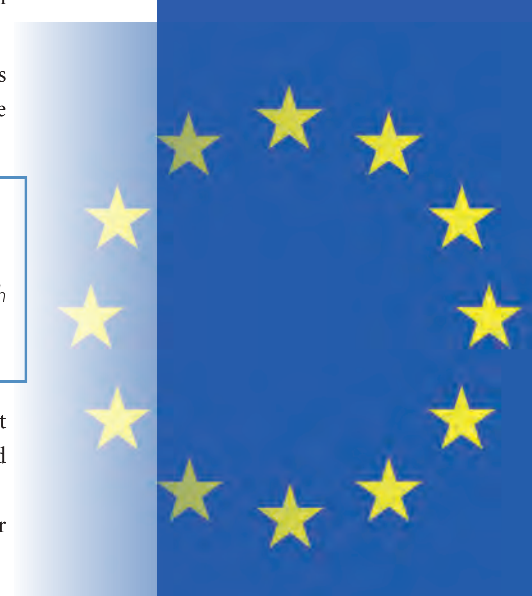

electro optics

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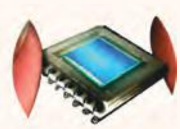
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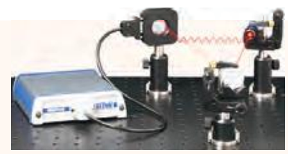
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Interview PhotonDelta Eindhoven

What PhotonDelta plans to do next?

Photon Delta
Integrated Photonics Ecosystem

"The Dutch are up to something" by Jonathan Marks • Ewit Roos

On April 25th 2016, a new organisation PhotonDelta went public.

"Think of PhotonDelta as a global business accelerator ", explains its enthusiastic Managing Director, Ewit Roos.

"We're entering the scale-up phase of this industry. Sometimes, the technology is ready but not at the cost-level for industry to implement. We need to change that. That's why we're accessing technical excellence that you'll find across the Netherlands. There is world-class expertise clustered around the high-tech cities of Eindhoven, Enschede and Delft."

"There has never been a shortage of Photonics startup companies in Europe. But a fragmented approach to building the multi-billion Photonics business is never going to scale. Major investors only really become active when technologies have validated themselves and are ready to scale-up to manufacturing".

Ambitious Targets have been set.

We're approaching the halfway point in the Juncker Investment Package from the European Commission, which means that € 315 billion Euros will be invested over the next two years.

The goal is to create strategic innovation hubs across Europe.

Eindhoven University of Technology and its local partners have identified Photonics as one of those strategic disruptive technologies they can focus on. The launch of their new Integrated Photonics Institute will help expand research that's the engine behind a much broader total optical technology market. Integrated Photonics makes things go 1000 times faster, 1000 times more energy efficient and copes with 1000 times more bandwidth.

We've learned to collaborate

So why are a disproportionate number of startup success stories coming out of this part of Western Europe?

The answers may lie in a recent report by Erasmus University in Rotterdam. Professor Henk Volberda leads continuous research into innovation. He concludes that "most CTO's don't realize that only 25% of innovation success depends on technology investments. The other 75% comes from factors including leadership style and co-creation with trusted partners."

This explains why PhotonDelta is building a European-wide "end-to-end ecosystem" of researchers, chip designers, foundries and software developers rising up to meet these challenges. It's also a great example of a trusted, collaborative network that already stretches across Europe and beyond.

Jonathan has spent over 35 years in broadcast media, the last 15 of which have been exploring how new media technologies are changing story-telling. He has a heritage in broadcast media with Austrian Public Radio, BBC World Service and Radio Nederland Wereldomroep. Since 2003 he has been exploring relevant new media technologies as an independent analyst and writer. Today, he is Director of Disruption at Critical Distance BV, an international guild of talented leaders, producers and trouble-shooters. The team specialises in helping high-tech scale up companies build an international media strategy. This requires building an open narrative and doing independent, investigative journalistic due-diligence. In recent years, Jonathan has been embedded in the European high-tech startup scene. His current focus is on photonics and advanced sensors.

Thanks to pioneering work led by researchers at Eindhoven University of Technology, the cost of manufacturing a photonics chip in Europe has dropped from € 200,000 to around € 10,000. Some say that the Dutch have "democratized photonics". Because by dramatically lowering the cost of entry, photonics development has been opened up for high-tech start-ups, small businesses and student researchers.
So, instead of one company making one chip on its own, next generation foundries like Smart Photonics in Eindhoven or LionIX International in Enschede have developed standard procedures so that several companies can share space during the production of single chip.

Building on successful initiatives

The choice of name is deliberate! As European Commissioner for the Digital Agenda, Neelie Kroes was instrumental in ensuring that Photonics became one of six Key Enabling Technologies in the European Commission's Horizon 2020 program. In January 2015 she became special envoy for StartupDelta.

During her address to the Global Venturing Summit in 2015, she explained why they selected the name "delta". "Of course, it reflects the landscape of The Netherlands" she said. "But moreover; it is the universal symbol for change, creating something radically new and scaling it to the next level. This is the exact opposite of creating incremental improvements on what is already known. To do that we need to focus on clusters of excellence".

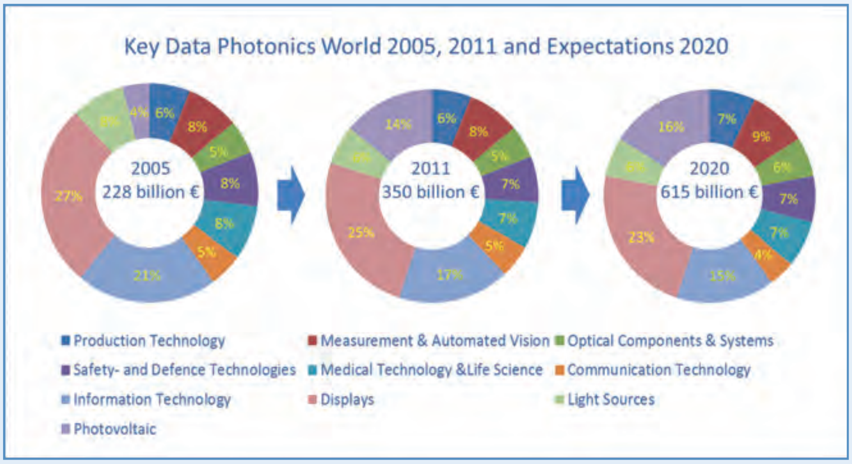
PhotonDelta is busy connecting those clusters of excellence emerging in Photonics. "Our role is to actively connect world-class photonics research with business and investors", continues Ewit Roos. "So we're working to amplify existing initiatives and kick-start new ones. Europe still has a 2-year head start by having all the pieces of the puzzle in place."

Optics technology key to solving the bandwidth crunch

The exponential demand for bandwidth in our world means that light has replaced copper as the enabler of the Internet.

- Over 1.5 billion smartphones are being sold worldwide each year, each demanding access to a data centre.
- Every second, two households are being connected to the fibre-optic Internet infrastructure.
- And every 18 months, the amount of data doubles for each connection.

Currently around 4% of the world's energy is used to power datacenters. But that's growing exponentially, so that by 2021 it means 85% of the world's energy is being used for datacenters.



Using light instead of electrons is the key to solving this energy challenge. At Nanolabs in Eindhoven and Enschede, researchers have been shrinking electronic components like lasers and optical sensors to a scale hundreds of times smaller than a single living cell. By putting these components on a single platform, integrated photonics is dramatically reducing the energy consumption.

Photonics is the engine driving other key areas

Photonics is also helping to revolutionize medicine and aviation. Chips from LionIx International are reducing the cost of human DNA Sequencing from US$ 10 million to nearer US$ 1000. Sensor applications in smart power grids, airplane wings, autonomous cars, intelligent buildings and industrial process control will contribute significantly to more efficient use of resources and meeting today's environmental challenges. Dutch scale up companies like Effect Photonics & Technobis are working closely with customers on their path to scaling internationally.

Local Chip Fabrication is key to the ecosystem

Last September 2015 saw the launch of commercial Indium Phosphide chip production on High Tech Campus Eindhoven. The company, Smart Photonics, has developed a unique pure-play approach, which dramatically cuts development costs and accelerates the time to market. This chip production line is at the heart of the commercial ecosystem that's being built in the Netherlands.

Staying Light Years Ahead

Disruptive innovation comes when these young companies get access to the knowledge already gained by high-tech enterprises and applied research institutes.

At this early stage, governments still need to support applied research and startups so that can reach the stage where their technology is ready for manufacturing. In hardware, it can take anything up to a decade to see the results. Manufacturers want reliable, tested, stable systems. Remember, the cost of recall these days is astronomical.

But the major investments made by city, regional and national governments in 2013 are starting to pay-off now as these technologies emerge from the lab. Eindhoven University spin-out, EFFECT Photonics, recently announced its optical 'System-on-Chip' photonic integration technology. It's a major contribution to greatly reducing the cost, physical space and power needed per connection.

Building talent for tomorrow

There are now software platforms, which help designers, make chips without having to understand the extremely complex physics that's going on inside. In Brainport Eindhoven, they are seeing a boom in the number of companies investigating the possibilities of photonics.

And in Twente they are preparing training courses at both University and HBO/MBO level so that as these businesses scale, there will be a pool of local talent to fill the new jobs.

PhotonDelta is the catalyst to make more of this happen!

Open Collaboration is key to maintaining Europe's Lead

"We've analysed the success of microelectronics. Now we're putting those lessons learned to work for integrated photonics," says Professor Meint Smit of Eindhoven University of Technology.

"The challenge in this business of integrated photonics has been the cost of making a chip prototype. If you develop a chip it always takes 2-3 runs before you get it right, because the chip never performs exactly as you expect."

"Traditionally, one process run currently costs at least € 200,000, if you do it on your own. So this is a huge barrier for small companies. But if 20 users can share the same wafer, then the costs drop to € 10,000 each and that's within the scope of many startups. You get 8 identical cells back from the foundry, which you can test, and measure. You can then iterate the design, so that the next run gives even better results."

JePPIX brings the community together

Nine years ago, Eindhoven University of Technology (TU/e) was instrumental is connecting a group of key European players in photonics. An organization called JePPIX connects those designing next generation applications with the four photonics foundries (chip-factories) in Europe, two of them in the Netherlands.

JePPIX has been extremely successful in bringing together the European Indium Phosphide community and those working with low-loss TriPleX technologies. More than 250 members are scaling the generic foundry technology infrastructure. 75% of the members come from outside the Netherlands and nearly 60% are from industry.

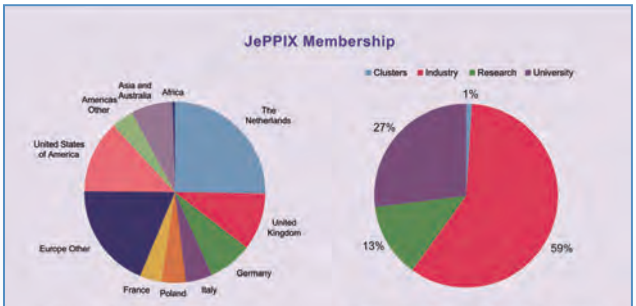


Figure 10 JePPIX currently has more than 250 members.

Figure 11 More than 50% of the JePPIX members are from industry.

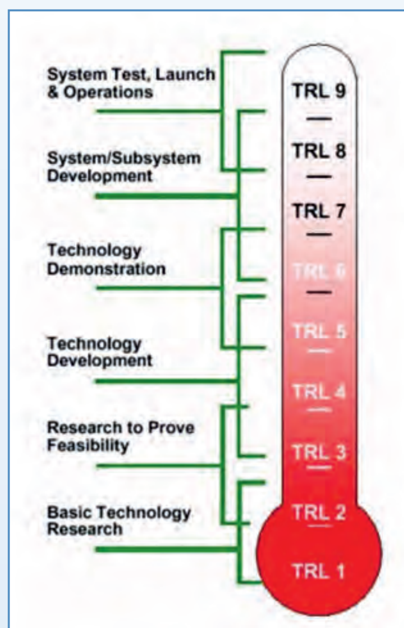
Coordination is essential for the success of the generic approach. That's because the work of many independent businesses needs to be closely coordinated. It is spread across process development, chip fabrication, packaging, software development, design and training. The organizational similarity in handling Multi-Project Wafer projects explains why JePPIX supports both InP and TriPleX technologies. There is also an increasing degree of cross-over between InP technology and low-loss dielectric waveguide technology for a range of applications.

And look at the work Jeppix is doing with its member to organize intensive courses in Photonic IC design. With MPW runs ramping up, there's a growing need to train new users on how to use the new Photonic building blocks.

Closing the gap between lab prototypes and production

Professor Kevin Williams leads the Photonic Integration group at COBRA, one of the world's top institutes in the field of optical communications and a founding member of PhotonDelta.

"University Research labs typically work on projects at the very early stage of development, the so-called technical readiness level of 1-3, originally developed by NASA in the 1970's" says Kevin. "But businesses and investors generally get interested when the product has reached level 6 or above when it is ready to be manufactured. In other words, the company has not only made a prototype, it has built a proven path to scale-up production."



"Previous programs between COBRA and our industry partners have taken the readiness level from 2 to 4. We need to take it further to reduce the level of business risk. The next phase for the eco-system will be pilot production to learn how to make PICs for many markets at the same time and in volume with marketable yield and performance. Our open access approach enables the broadest range of innovators to join this endeavor."

That development gap between technical readiness levels 3-6 is often the "valley of death" for hardware companies producing chips or applications. Until relatively recently, it has been the biggest reason for European research teams to head for the US or Asia where there is more of a willingness to bridge this funding gap with investments.

Simplifying the Chip Making Process

"In electronics you've been able to design chips using a process design kit (PDK) for decades. You build your design virtually, test and optimize it, knowing that what you send to be fabricated will perform in the way you expect. Making a PDK delivers more than just a model though. You're also connecting design software with process control, which is a method to understand and improve yields." "With photonics, it hasn't been as easy. Photonic devices can interact and behave in complex ways. There may be instabilities that occur that you didn't expect. So far you needed several trial runs before the fabs can get their tolerances in spec."

"Thanks to the recently concluded Paradigm research project, led by Professor Meint Smit, we've now reached a stage where our Process Design Kit can be used by any chip designer. You don't need an-depth knowledge of the underlying technology or the fabrication process. All you need is a clear understanding of the end goal. We've now reached a point where the European fabs of photonics chips are offering process design kits at the building block level. This means that the same stable process can be used for many different circuits."

The PDK in practice

"You pick your laser and place where you want it on the chip. Under the hood, there are sophisticated simulation tools, which predict what a circuit will do, and layout tools, which enable the fabs how to make it as intended. All this reduces the number of test fabrication runs that need to be made before a new chip design matches the original performance specifications. And that helps reduce the hardware development costs"

"On the research side, we have every confidence in these technologies. But we need to build more business confidence, which includes a pilot line. "

"That's a task which PhotonDelta is perfectly positioned to do. "

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Uw logo hier? Wordt lid van PhotonicsNL!

Photonics in Twente

Sonia Garcia-Blanco • Twente University

The Twente region constitutes a nurturing ecosystem for photonics. The University of Twente has been recognized the most entrepreneurial university in the Netherlands. More than 400 enterprises are located in the Kennispark Twente, the high-tech business park surrounding the university. Many of them work in the photonics field, covering the supply chain from materials and devices to bulk optics. Optics and photonics research at the University of Twente is grouped under the umbrella of the "Applied Nanophotonics" (ANP) cluster, embedded in the MESA+ Institute for Nanotechnology. The research, ranging from the very fundamentals of light-matter interactions at the nanoscale to applied nanophotonic devices, constitutes a base of knowledge generation that leads to future applications. The combination of fundamental and applied research at the university, with the excellent high-tech infrastructure, including the MESA+ Nanolab and the High Tech Factory, together with the high-tech companies established in the Kennispark create a truly innovative environment covering the whole innovation chain.

UNIVERSITY OF TWENTE: FROM FUNDAMENTAL RESEARCH TO INTEGRATED PHOTONICS

Disordered Nanophotonics Materials

Light propagation in ordered and disordered nanophotonic materials is an exciting research topic that can lead to the better understanding of the properties of light and how to control it at the nanoscale. Researchers from the Complex Photonics Systems (COPS) and NanoBioPhysics (NBP) groups have demonstrated non-invasive imaging through scattering media (Figure 1).

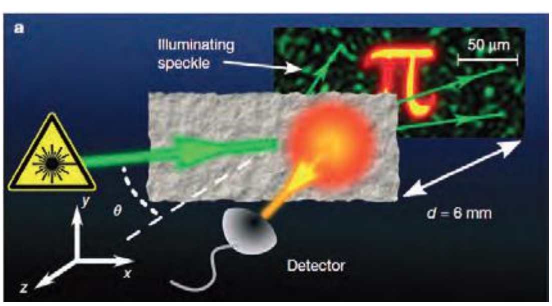


Figure 1: Imaging of a fluorescence object through an opaque medium: A monochromatic laser beam illuminates the opaque layer of thickness L at an angle θ. The fluorescence object is hidden 6 mm behind the layer [1].

The physics learnt from that study led to several new developments including speckle correlation wide-angle fluorescence microscopy, exhibiting resolution of ~100 nm for visible light, a sub-100 nm flat scattering lens, programmable bulk-optical components and more recently, to the experimental demonstration of two-photon quantum interference in an opaque scattering medium that intrinsically supports 103 transmission channels.

Plasmonics

The use of plasmonics to control light-matter interactions is another research subject of several groups of the ANP cluster. Researchers at the NanoBioPhysics (NBP) group have shown that silver/gold nanoparticle dimers enhance the fluorescence signal from dye molecules located at the "hot spots" in between the two particles leading to enhanced sensitivity sensors. DNA-induced dimerization of nanoparticles of the correct metal and size shifts the scattering frequency, which can be detected by a simple color detection scheme (Figure 2). In collaboration between the NBP and COPS groups, the proximity to a metallic interface was used to modify the local density of states (LDOS) for a complex energy transfer coupled emitter pair to gain a deeper understanding of the fundamentals of nanoscale energy transfer. Further in the COPS group, the high

Sonia M. García-Blanco is an Assistant Professor in the Optical Sciences Chair of the MESA+ Institute for Nanotechnology. She graduated with an MSc degree from the Universidad Politécnica de Madrid in 1999. She carried out her master thesis work at the IBM Almaden Research center, in Almaden, California, US. She obtained her PhD degree from the University of Glasgow in 2003, for her work on integrated optics for biosensing. After a two year post-doc at the University of Toronto (Canada) she joined INO (Québec, Canada) as staff scientist in 2005. At INO she led several multidisciplinary projects for several space agencies including the CSA and ESA. She was responsible for the 3-D photonic integration and wafer-level hermetic packaging activities of the company. In 2010, she joined the University of Twente as Tenure Track assistant professor, where she leads the Integrated Optical Systems (IOS) subgroup, which focuses on the development of novel active devices to be integrated as building blocks in passive technology platforms, the use of plasmonics in optical waveguides and optical sensing based on integrated optics.
Optical Sciences Group
MESA+ Institute for Nanotechnology
University of Twente

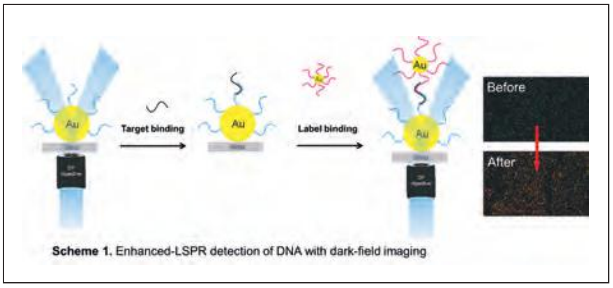


Figure 2: DNA sensing scheme based on target-induced dimerization of surface-based and colloidal nanoparticles [7];

confinement achievable in plasmonic waveguides has been exploited to propose a high resolution line imager (Figure 3).

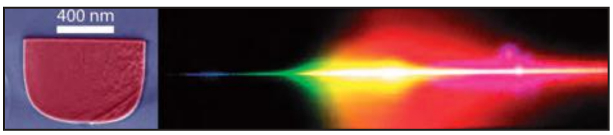
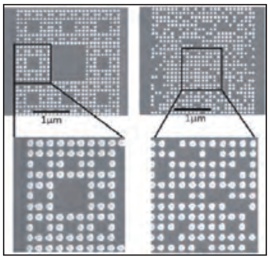


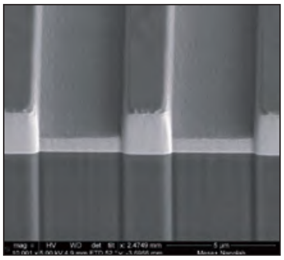
Figure 3a: SEM picture of an ultra-thick Si3N4 waveguide that has anomalous dispersion over the required wavelength range to support ultra-wide supercontinuum generation, seen in (b);

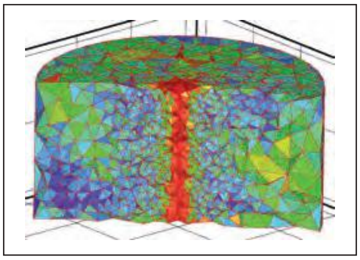
In the Optical Sciences (OS) group, plasmonic nanoantennas have been fabricated on single-crystalline gold flakes, giving superior control of size and shape effects with feature sizes down to 10 nm. An optical analog of the Sierpinski fractal antenna, routinely used in the rf region for broadband applications, was created to explore the effect of geometry on the system response in a matrix array of nanoparticles, while a phase array of nanoantennas was shown to be an effective directional emitter. Both passive and active control strategies have been implemented in the design of functional systems for manipulating light on the nanoscale. On a more applied level, the OS group experimentally demonstrated that the use of metal layers underneath the core of dielectric waveguides reduces the total losses of bends for small radii of curvature (i.e., between ~35 μm and ~6 μm). This discovery can pave the way to high photonic integration in low contrast waveguide platforms.

Advanced imaging and spectroscopy techniques

A large amount of research at the OS group has been devoted to the development of nonlinear microscopy, in which three optical fields create a pair of interfering Stokes-Raman pathways to the same vibrational state. Frequency modulating one of the fields leads to amplitude modulations on all of the fields, allowing to do imaging at high speed and free of non-resonant background, distinguishing between electronic and vibrational contributions to the total signal.
Identifying complex molecules often entails detection of multiple vibrational resonances, especially in the case of mixtures. Phase shaping of broadband pump and probe pulses allows for the coherent superposition of several resonances, such that specific molecules can be detected directly and with high selectivity. With the pulse shaped-CARS technique, developed at the University of Twente, an approach for combining spectral phase shaping and closed-loop optimization strategies to perform chemically-selective nonlinear microscopy has been developed. By introducing an additional intense laser probe beam that pre-populates an additional vibrational state that is non-radiatively coupled to the vibrational state probed by the CARS process, sub-diffraction limited CARS microscopy has been proposed.
Near-field scanning optical microscopy (NSOM) and photon scanning tunneling microscopy (PSTM) enables to look to what happens in close proximity, the near-field, of the nanostructures. Other characterization techniques used at the University of Twente that help understanding photo-physical processes taking place in the femtosecond to nanosecond time window are femtosecond transient absorption, time-resolved x-ray absorption and ultrafast photoluminescence spectroscopy. These techniques are used to study in real-time ultrafast light-induced processes both in materials with application in photovoltaics and solar-to-fuel approaches.







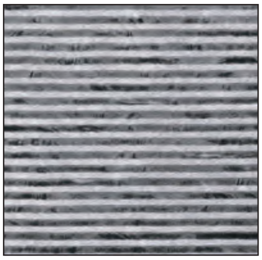


Figure 4a: SEM images of a Sierpinski carpet nanostructure and pseudorandom nanostructure fabricated by focused ion beam on a crystalline gold flake.
Figure 4b: High contrast waveguides on a thin membrane of potassium double tungstates on a SiO2 substrate.
Figure 4c: Adapted mesh and a posteriori error indicator to efficiently capture the singularity of the electric field in the time-harmonic Maxwell equations at the internal corner using discontinuous Galerkin finite element computations.
Figure 4d: High resolution TEM image of a Mo/Si multilayer mirror for the reflection of extreme UV radiation with near theoretical reflectivity.

The research particularly focuses at strategies to control and optimize the competition between ultrafast functional and loss pathways.
In a collaboration with materials scientists at the University of Twente, laser induced fluorescence (LIF) has been utilized to perform the spatio-temporal mapping of species in plasmas used for pulsed laser deposition of different oxide materials, such as $LaAlO_3$ and $SrTiO_3$.

XUV photonics

XUV light - light with a wavelength in the range from tenths to tens of nanometers - offers new physical insights. XUV light can trigger atomic and material processes that are otherwise unobserved, providing a new view on light-matter interactions. XUV light also offers the ability to image at the nanometer scale, and to perform materials analysis with sensitivity in the ppb range. These applications require high precision optics that reflect, focus, and filter XUV light. The development of such optics is the goal of the XUV Optics group: it addresses basic, nanoscale aspects of thin film optics and gears fundamental research to the specific needs of science and industry, as shown by the close collaboration with ASML and Zeiss. In the Laser Physics and Non Linear Optics (LPNO) group, high harmonic generation (HHG) at extreme intensities is investigated to generate ultrashort pulses in the XUV wavelength range. Wavelength tuning using phased shaped drive laser pulses permit tuning the XUV wavelength in an efficient way. Such radiation in combination with nano-structured optics can enable improved spectral control, microscopy and XUV lithography on the nano-scale.

Computational techniques

The Mathematics of Computational Science (MACS) group of the ANP cluster focuses on the mathematical aspects of advanced scientific computing. The two main research areas are the development, analysis and application of numerical algorithms for the (adaptive) solution of partial differential equations and mathematical modeling of multi-scale problems making these accessible for computation. Special emphasis is put on the development and analysis of discontinuous Galerkin finite element methods and efficient (parallel) solution algorithms for large algebraic systems. One of the important applications is in computational electromagnetics and nanophotonics.

Integrated photonics

On the more applied side of the research carried out by the ANP, the groups LPNO and OS, combine integrated optics with active materials to produce devices with advanced functionalities that access physics that would be not feasible using free space optics. The high confinement of the electromagnetic field in the core of optical waveguides permits exploiting non-linear phenomena in a power efficient way. When in combination with gain materials, devices such as supercontinuum sources, high gain on-chip amplifiers, tunable and narrow linewidth lasers can be realized. The passive materials available at the MESA+ Nanolab for the realization of optical waveguides are silicon nitride (Si_3N_4), silicon oxynitride (SiON) and aluminum oxide (Al_2O_3).
One of the research interests in this field is the combination of active materials (i.e., III-Vs, rare-earth ion doped Al_2O_3 and crystalline potassium double tungstates) with standard passive technology platforms (i.e., SOI and Si_3N_4 "TripleX") to provide novel building blocks with performance not achievable from standard devices. Other recent breakthrough in this area of research include the first demonstration of an optical field programmable gate array (FPGA) device and the demonstration of a silicon nitride circuit for time-bin entanglement, to be used in quantum computation.

3D silicon photonics

The ongoing success of the computer industry is driven by the continued miniaturization of computer chips, and by the integration of photonics ("Silicon photonics") to efficiently and quickly transfer large amounts of data. One way to allow for even more processing power is to devise chips that are stacked in all three dimensions in space, not just the two dimensions available to usual planar techniques. COPS scientists have developed a revolutionary process in collaboration with ASML, TNO, and Philips, to realize the 3D nanostructure shown in figure 5 in only two steps. In the first step ASML's advanced deep-UV lithography was used. Next the deep nanopores were etched using a plasma etch process. The new 3D structures possess a 3D photonic band

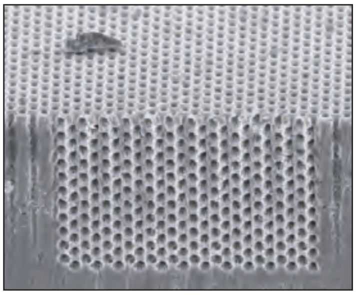


Figure 5: Electron microscope image of a 3D structure in silicon, consisting of a rectangular pattern of pores that cross at an angle of 90º. The top surface of the chip is visible in the upper part of the picture. Many very deep, straight nanopores are etched in the top surface. Subsequently an identical pattern of deep nanopores was etched in one step in the side of the silicon chip to yield the three-dimensional structure. An inadvertent dust particle is visible on the top surface. The 3D crystals revealed the first confirmation of Yablonovitch' 1987 prediction of inhibited spontaneous emission.

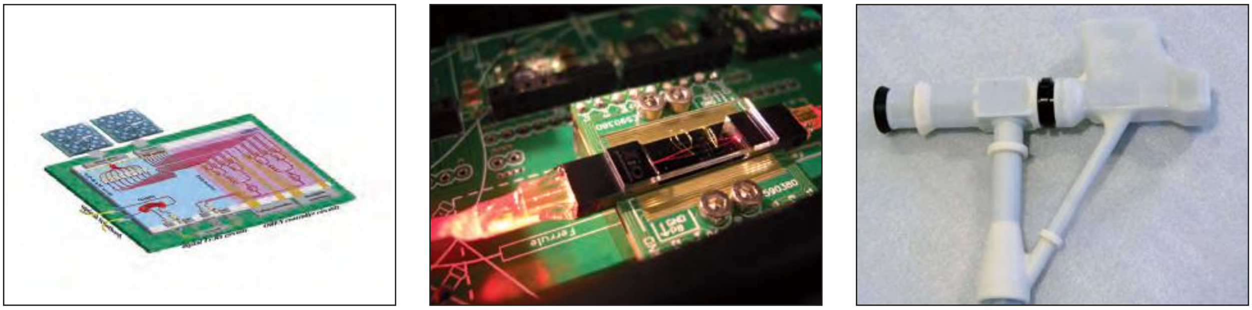


Figure 6 a: Concept of 5G transceiver module that will be developed by the HAMLET project consortium, which included Twente partners LioniX, SatraX and Solmates

Figure 6 b: Photograph of a package photonic integrated circuit chip from XioPhotonics

Figure 6 c: The Corimapper: a handheld retinal oximeter developed by Focal and fundus image acquired with it.

gap for light. In optical studies, strong reflectivity peaks were observed, with novel "sub-Bragg" diffraction behavior. With nonlinear optics, it was demonstrated that the band gap can be switched on ultrafast femtosecond times. Moreover, the excited state lifetimes of embedded quantum dots were found to be stabilized by the 3D band gap, which allows novel applications in chemistry, miniature threshold-less lasers, light harvesting, and lighting. Currently, the researchers are realizing a band-gap cavity and 3D cavity arrays by a new innovation of the 3D assembly method, to dope the crystals with functional defects.

PHOTONICS HIGH-TECH AT THE KENNISPARK TWENTE: FROM MATERIALS AND INTEGRATED PHOTONICS TO COMPLETE OPTICAL SYSTEMS

Novel materials layers

Solmates' pulsed laser deposition (PLD) platform is the next disruptive deposition technology following the adoption of atomic layer deposition (ALD) for thin film manufacturing. The technology uses a laser to create a plasma of the material to be deposited, enabling industrial quality deposition of new generation materials. An automated tool offers high yield, customized deposition of various 'More than Moore' materials on a wide variety of different substrates. Solmates has optimized several processes for enhanced LED performance. They can reduce internal reflections by using nano-porous optical layers. Several materials can be tuned to the exact desired refractive index, or even applied with graded index. The PLD process has been developed for the deposition of several materials common in photonics (i.e., BaTiO3, ITO, LiNbO3, PLZT, Y3Fe5O12, ZnO).

Integrated photonics

From the three photonics integrated platforms considered "generic" (i.e., silicon on insulator, indium phosphide and silicon nitride), the silicon nitride platform, commercialized under the name TripleX by LioniX, has its origins in Twente. LioniX developed this technology, which enables a new class of integrated-optical planar lightwave circuits using low-cost, CMOS-compatible fabrication equipment. The waveguides are based on LPCVD processing of alternating Si3N4 and SiO2 layers. These mediums to high index-contrast waveguides exhibit low channel attenuation and are suitable for operation at wavelengths ranging from 400 nm through 2.35 µm, which make them suitable for applications ranging from telecom to sensing. Several other photonic companies in the area, some of them spin-offs from the university, utilize LioniX waveguide technology for different applications.

SatraX has developed an optical chip-platform that includes tunable delays, phase shifters and filters to create broadband beamforming modules for phase array antenna plates (Figure 5a). The developed integrated chips, which use LioniX TripleX Si3N4 waveguide technology, permit a dramatic reduction of the size, cost and ease of operation of the beamforming modules. SatraX is an innovative company pioneer in the field of Microwave Photonics. Together with LioniX, Solmates and other European partners including Linkra (Italy), Fraunhofer HHI (Germany) and the National Technical University of Athens, SatraX will develop optical beamforming networks for next generation 5G-networks. Very low power consumption will be achieved by the integration of the piezoelectric materials developed by Solmates onto LioniX's TripleX platform.
See also: www.hhi.fraunhofer.de/press-media/news/eu-project-hamlet-started-in-berlin.html)

XiO Photonics uses the TriPleX waveguide technology to create full assembled photonic modules for applications in life science like bio-sensing, DNA-sequencing and confocal microscopy. They optimized the TripleX waveguide and the assemble methods for use in the visible and near infrared range. The photonic IC is assembled with fibers and driving electronics into a full module. An example is the integrated laser beam combiner that combines *several visible laser outputs to a single fiber and has use in confocal microscopy (Figure 5b).*

Optisense was formed in Enschede in 2005 to commercialize a technology relating to optical sensors that originated at the University of Twente. Optisense has developed a unique, optical sensing, platform technology for the rapid detection of chemical and microbiological compounds in water and other liquids. Optisense' patented optical chip can be deployed in a generic sensor for continuous process and quality monitoring or in a target sensor for the in-situ detection of specific substances. Optisense has commercialized two products for the drinking water industry: EventLab, a generic contamination sensor for distribution networks, and MiniLab, a sample-based sensor for detection of individual compounds. Other potential applications for Optisense' technology include water treatment, process industries (e.g. food, beverages and pharmaceuticals), agriculture and medical diagnostics. Optisense manufactures its optical sensors at the MESA+ Nanolab facilities.

BioVolt was established in 2013 with mission is to improve people's lives by personal diagnoses of health, wellness and analysis of food. BioVolt' approach to achieve this is to extend the human senses through making available on-demand molecular sensing tools that deliver provide the crucial and timely information to diagnose diseases at an early stage or to avoid disorders altogether. These tools will support data-intensive management through regular monitoring of biochemistry. BioVolt' sensor solutions are being developed in Twente in collaboration with several groups of the University of Twente and Hogeschool Saxion and are based on world leading and patented photonic technology also developed in Twente. BioVolt implements the convergence of this photonic platform with proven and innovative (bio)chemical techniques and information systems to achieve the ultimate in precision and miniaturisation in everyday use. Throughout this product research and development programme, the company adheres to the most rigorous scientific principles and external validation.

Photonics Software

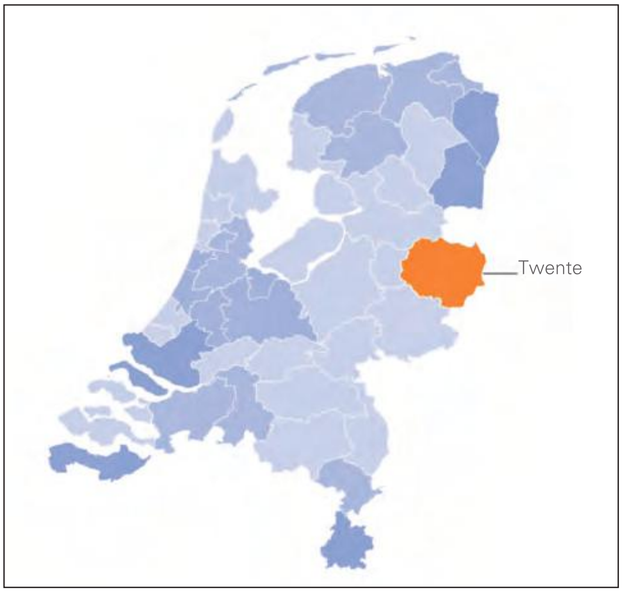
Pioneering photonics design automation already since 1991, today PhoeniX Software has a global presence and is a trusted and well-recognized partner for a large number of organizations. The software allows the easy and cost-effective realization of integrated photonics chips and systems, serving customers ranging from large OEM's to start-ups and including some of the world's top universities and research institutes. As a leader in Photonic IC design solutions, PhoeniX B.V. continues to develop the market by anticipating market demands and customer needs, offering world class design flows and access to all relevant fabrication technologies for its customers.

Optical systems

Bulk optics, sometimes in combination with integrated photonics, is also a very important subfield of optics, which is represented in the Twente region by Focal. Focal vision & optics is active as an integration and development partner in the fields of industrial precision inspection, medical optical systems and high-tech optical systems, serving clients in automotive, life sciences and semicon industry both in the Netherlands and abroad. Focal conducts design and engineering activities in a multidisciplinary approach, with internal expertise in optical and opto-mechanical engineering, machine vision and system engineering. Main services offered by Focal include high-level requirement engineering, concept optical design, prototyping, detailed engineering, system integration and delivery. One of the latest developments is the Corimapper, a retinal oximeter with a hand-held functionality, which images simultaneously the fundus with two well defined wavelength bands to estimate the blood vessel oxygenation saturation (Figure 5c).

Conclusion

The Twente region is a hub of photonic activity. Together, the University of Twente and the high-tech companies based in the Kennispark Twente, cover the full photonics innovation chain. But Twente is not an isolated island. Both researchers at the University and the different photonic companies work in close relationship with other researchers and photonic industry in other parts of the Netherlands, strengthening Netherlands' position in the photonics field.



Applied NanoPhotonics Cluster (University of Twente):

The Applied NanoPhotonics Cluster (ANP) of the University of Twente unites the research efforts of 6 optics and photonics groups: Optical Sciences (OS), Complex Photonic Systems (COPS), Mathematics of Computational Science (MACS), Laser Physics and Non-linear Optics (LPNO), Nanobiophysics (NBP) and XUV. With over 90 researchers, ANP is the largest unit of its kind in the Netherlands, carrying out optics research spanning from fundamental principles, such as the study of light-matter interactions at the nanoscale, the nano-manipulation of single quantum emitters and the coherent control of molecules with amplitude/phase tailored ultrashort light pulses, to more applied research, including the development of on-chip novel active devices and coatings to manipulate light of extremely short wavelengths. Advanced microscopy, spectroscopy and imaging techniques (such as hyperspectral coherent antistoke Raman spectroscopy (CARS) and near-field microscopy (NSOM)) are available tools that permit getting insight of what is happening at the nanoscale.

Twente Graduate School "Advanced Optics"

The 4-year PhD program in Advanced Optics offered by the University of Twente aims to train young scientists in this fast growing field. The program focuses on advanced optics, with a particular focus on applied nanophotonics, congruent with the eponymous research cluster within MESA+.

MESA+ Nanolab

MESA+ has a 1250 m2 state-of-the-art NanoLab, which consists of three closely intertwined units: the cleanroom, analysis facilities and the BioNanoLab. Research at the nanometer scale needs a laboratory with extreme specifications, whereas the NanoLab is constructed to meet such high standards. NanoLab NL has the aim to build up, maintain and provide a coherent and accessible high-level, state-of-the-art infrastructure for nanotechnological research and innovation in the Netherlands.

High Tech Factory

High Tech Factory is the production facility for businesses engaged in work on microsystems and nanotechnology. It is located on the campus of the University of Twente. The NanoLab is open to the companies established in High Tech Factory. Several of the photonic industries in Twente are located or affiliated with the High Tech Factory.

Kennispark Twente

The Kennispark Twente is an innovation flagship. It is home to over 380 innovative companies it is one of the largest innovation campus in the Netherlands. LioniX, XiO Photonics and SatraX - since April 2016 under the flag of LioniX International BV - PhoeniX, Optisense, Focal, BioVolt and Solmates are all located in the Kennispark Twente, just meters from the University of Twente and the MESA+ Nanolab. ◆

Ed. Because of practical reasons the printed version of this article has been shortened. The full version of the article including all the references is published on our website www.photonicsNL.org.

Additional attention for Photonics at Technology for Health

On October 11th and 12th Mikrocentrum organises the 9th edition of Technology for Health. This event is the Medtech R&D exhibition in the Benelux and will take place in the Congrescentrum 1931 in Den Bosch (the Netherlands). This trade fair is the yearly venue for professionals who are working all around the development of medical devices. Suppliers, developers and service providers meet for a yearly update out of the working field and to start up new projects.

Development stage

At this moment Technology for Health is often still in the beginning of the value chain. The so called "Death Valley". During this event products aren't finished yet, and especially the development phase is of high importance in the medical world.
The key issue of a good innovation is the right preparation and the involvement of the right person in an early stage. And that's why Technology for Health is the place to meet.
Visitors have a good idea, are developing in this area, or are looking for suppliers who might be able to contribute in the development. Visitors are from large companies as well as smaller players in the market.

Biophotonics for Health & Life science

Biophotonics is, with a present, worldwide turnover of € 35 billion* and a yearly growth of 10%, one of the fastest growing technology markets, especially inside Health & Life science. The estimation is that this will even double in 2020. Within the EU this is being seen as the most important market for new activity and new employment. The OASIS-project, initialized by the EU-commission, is an exquisite example, because the international cooperation between universities, research facilities, hospitals and enterprises is an important success factor to get to new and innovative end products and to strengthen our European competitor position compared to countries as the United States and Asia.

* From "Biophotonics Market, Focus on Life Sciences & Health Applications" report from Yole Development & Tematys.

Extra attention for Biophotonics as Key Enabling Technology

To make this growing technology more public to the audience a substantive workshop will be organised during the Technology for Health. Photonics companies can expose on the PhotonicsNL cluster stand at reduced rate. Would you like to join too?

Please contact: Saskia Baeten: s.baeten@mikrocentrum.nl, +31 402 969 922 or
Guus Taminiau: guus.taminiau@photonicsnl.org, +31 628 615 334

AGENDA

Date: 1 – 2 June 2016
Event: Photonics Event 2016
Where: Veldhoven, NL

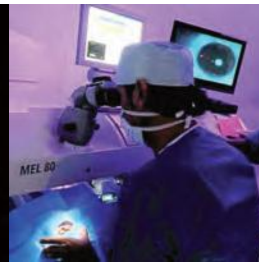
Date: 2 – 3 June 2016
Event: European Photonics Venture Forum
Where: Eindhoven, NL

Date: 28 August – 1 September 2016
Event: SPIE Optics + Photonics 2016
Where: San Diego, US

Date: 11 - 12 October 2016
Event: Technology for Health
Where: Den Bosch, NL

Date: 28 January – 2 February 2017
Event: Photonics West 2017
Where: San Francisco, US

Please see our website for more information: www.photonicsnl.org

Fast 3D cameras using single photon detectors

Fastree3D develops sensors for fast detection of distance and movement. They provide fast measurement rate, high 3D resolution, and optimal signal/noise ratio. Applications include automatic robotics, automotive safety, guided vehicles and smart buildings.

Fastree3D announces a new generation of flash LIDAR (Light Detection and Ranging) for fast 3D cameras. The digital integrated circuit includes a single photon detector array, digital time counters for direct measurement of single time of flight time implemented on CMOS semiconductors.

Meeting requirements of fast automotive and robotics applications

The requirements for automotive safety, autonomous vehicle guidance cannot entirely be met with 2D image or video processing nor slower laser scanning or indirect time of flight sensors available today. Our sensors are designed for:

- High speed response: capturing 30 m/s movements without blurring (> 100 fps)
- High 3D resolution: resolution < 0.1% across field of view requires distance resolution >5mm and array of 1K-19K pixels (for 2D image sensor fusion).
- High SNBR and dynamic range to operate under full sunlight or at night.
- Illumination / detection efficiency: within eye-safety constraints with optimal price/performance.

Single photon detector arrays for direct time of flight

Fastree3D implements large arrays of Single Photon Avalanche Diodes (SPADs) integrated within a CMOS digital circuit computing direct time of flight (ToF). A direct ToF system calculates the distance by measuring the time for light emitted by a light source to be reflected from the target.

The SPAD array detector implement opto-semiconductor devices providing photon detection even with weak light reflection. A time resolution of >10 ps can be improved with on-chip statistical averaging. SPADs replaces Avalanche Diodes (APDs) or Silicon photomultipliers (SiPM), as both technologies require opto-mechanical scanning elements to provide angular resolution. An additional advantage is the integration on a single circuit of the digital signal processing (DSP) to increase measurement frequency and reduce external noise. The DSP implements time-correlated Single Photon Counting, which provides a high signal/noise ratio in the presence of strong solar illumination. At a system level, the advantage comprises a 10x to 50x gain in speed, with cm resolution.

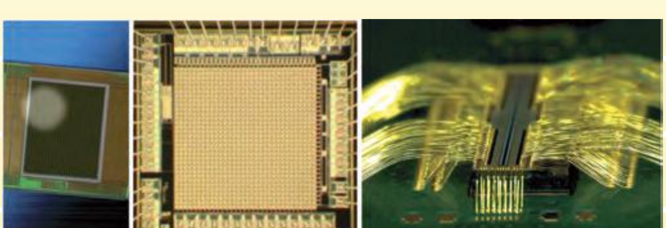
Characteristics

- Speed 200-1000 fps
- Resolution: 160x120 pixels (QQVGA), 10-40ps (1.5-6mm)
- S/N Filtering (time correlated, time gating, 5% PDE)
- Illumination: 850nm VCSEL arrays at 1-10 MHz PRP
- Emulator with FPGA processor available Q1 2017

Company information

The company has research at TU-Delft and offices at EPFL (Swiss Federal Institute of Technology, Lausanne). It welcomes industrial partnerships in Automotive and Robotics sector. I: www.fastree3d.com

E: info@fastree3d.com   P: +41 22 3661000



Left: CMOS SPAD 160×128 pixel array sensor with microlens array, mounted on a printed circuit board. (EU MEGAFRAME project)
Middle: CMOS SPAD 160×128 pixel array, capable of performing one million ToA evaluations per pixel per second at 52 ps time resolution. (EU MEGAFRAME project)
Right: CMOS SPAD 256x1 line sensor bonded on a carrier PCB to connect to an FPGA motherboard. The FPGA-basded TDC measured histogram shorter than 100 ps FWHM using a laser pulse with 50 ps FWHM allowing 3D time-of-flight. (S. Burri et al. Published: April 2016, Proc. SPIE 9899, Optical Sensing and Detection)

Avantes BV branch winner at *De Succesfactor*

Avantes BV winner 2016 in optical instruments branch

Avantes BV has been announced by the *Nationale Business Succes Award Instituut* as winner 2016 in the optical instruments branch. According to the Nomination Committee it has evolved into a leading international enterprise, with a very strong position and an outstanding reputation. "Avantes knows how to combine its comprehensive knowledge of optical instruments with an innovative approach, which results in a high level of contentment with its customers".

The company started in a garage, but nowadays that's quite different, as there are locations worldwide and a headquarter in Apeldoorn of 2500 sqm. Worldwide 90 people are daily active in developing, building, selling and shipping spectrometers, light sources, optical fibres and accessories for its valued customers. Applications can be found in various markets, such as medical technology, food industry, environment (detection systems in air and water), chemistry, mining industry and metal industry. Avantes BV has been founded in 1994.

The Nomination Commission of the *Nationale Business Succes Award Instituut* finds in Avantes BV a stable, advanced organisation that will gain numerous successes in the future according to expectations. "Innovation is the keyword at Avantes, as it is continuously improving its products and services and tuning this in in the customer's needs. The enterprise offers services that mainly have to be developed once the question is being asked. Therefore R&D is a matter of life".

Worldwide leading

Avantes is a worldwide leading manufacturer of Fibre Optic Spectroscopy-instruments and -systems and provides modular build custom-made for very customer specified questions. Its miniature spectrometer systems are designed to achieve measurements and research and to make analysis in the light-spectrum. "A spectrometer is a tiny high-tech measuring-instrument that knows many applications. For example it can measure whether a birthmark is malignant, how many fertilisers the ground contains or how many exhaust gasses can be found in tunnels. With a combination of high-tech hardware and software Avantes supplies measuring-solutions and useful information at the highest level", according to Robert Zwaan, principal of the daily Nomination Commission.

The highly-educated employers form the assets of the enterprise. Knowledge management (developing, sharing and securing) occurs internal, but also external at the high-tech industry. The most important clients, amongst which the most prominent universities in the world, are a source of innovation. In this way Avantes can always be leading.

"Listen very carefully and being very market-oriented, that's the secret. Although other companies might do the same, but Avantes just does it somewhat better", according the Nomination Commission. Enthusiasm, passion, innovation ability, courage and vision, including a strong focus on the customer make the absolute world's best enterprise and the deserved branch winner. Absolutely worth the award for most innovative enterprise, but maybe even a likely candidate for the final conquest in 2016.

More information: **www.avantes.com**

About the Nationale Business Succes Award Instituut

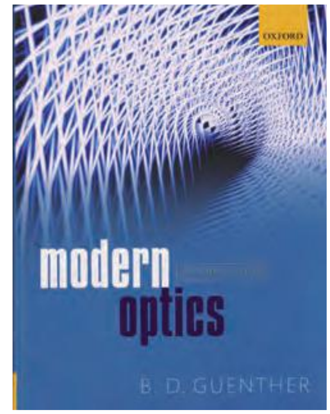
Since 2011 the Nationale Business Succes Award nominates yearly the best enterprises of the Netherlands in specific branches bases on strict selection criteria. Based on research a Success Award is being granted to enterprises with excellent results in their branch and being a bright example of successful entrepreneurship. The Nationale Business Succes Award is the first and only yearly entrepreneur-price of the Netherlands, including its own telecast-program and a first prize of € 100.000.

The mission of the Nationale Business Succes Award Instituut is dual: sharing actual innovations and knowledge about success factors of entrepreneurships in the Netherlands via (cross medial) interest, and strengthen the success, brand reputation and the company pride of the nominated enterprises through this entrepreneurship-prize and the platform of the Nationale Business Succes Award.

The present edition of Nationale Business Succes Award (2016), including the related telecast-program De Succesfactor, has started in January and can be seen weekly until the end of 2016 at RTL 7, Sundays at 13:55.

A Study of Modern Optics for versatile application

Jan Broeders, *Optische Fenomenen* and your steady book reviewer, www.optischefenomenen.nl



The comprehensive study and reference book Modern Optics provides users with an overview of the basics and principles of optics in general and the modern and innovative applications in particular, such as laser optics, optical fibers, holography and medical imaging techniques. The fundamental approach of optics in general makes this textbook ideal for use by students and teachers in study fields of physics and photonics. The description of the optics is based on the principles of Maxwell's equations. In addition to this basic treatment of all forms and phenomena, the author gives users an overview of all the common problems of the theoretical background and practical use of optics. Recently a second edition of this widely used textbook has been published. The content has been created from a combination of lecture notes and additional explanations of various subjects out of the fields of physics, mathematics, electricity and the phenomenon of magnetism, and the experiences and contributions of teachers, students, supervisors and colleagues by using this comprehensive textbook on colleges, universities and trainings. Also some research departments of the Duke University contributed their knowledge to sections of the subject materials on optical communications, holograms, lasers and modern applications of imaging techniques for medical use. For a successful use it is necessary that the students have prior knowledge of basic physics and that they are familiar with differential equations. The Modern Optics textbook contains fifteen chapters with specific topics, such as the Theory of wave motion and electromagnetism, Reflection and refraction and Interference. These topics are followed by Geometric optics, Coherence and Diffraction. Special attention is being paid to the Holography , Optical modulation and Non- linear optics. Each section concludes with a summary, various issues, a compact literature overview and occasionally with a theoretical or practical addition. A comprehensive index makes this extensive textbook complete.

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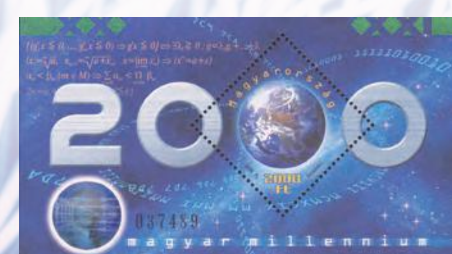

Stamps can contribute to the enrichment of our knowledge of optics and holography .